Characterization of laser welds between Nitinol and stainless steel, for medical components

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Nickel-Titanium (NiTi) shape memory alloys are often used in medical component devices, for instance as guide wires for neurological surgery applications. Manufacturing of such devices becomes more and more challenging, especially considering the need to join them with other metals. This study is focused on the NiTi and stainless steel (SS) couple, which is very interesting for the medical components industry.

Laser welding offers several advantages over other conventional joining techniques such as friction stir welding or resistance butt-welding. Indeed the high power density and fine focus delivered by lasers makes this process faster, more flexible and more convenient to use for complex geometries. However, the high thermal gradient, fast cooling rate and very localized heat-affected zone associated with this process also induces several damages, such as liquation at grain boundaries or hot cracking. This is particularly the case when very hard and brittle materials, with a well-defined stoichiometric composition (such as TiFe or $TiFe_2$, in the case of NiTi and SS) are involved, either as base materials or as a result of alloying in the weld itself. Sometimes, the crack is initiated by a local default (like a porosity or a remaining part of the oxide skin present on the NiTi wires) and its driven force is given by the thermal contraction due to the thermal gradient [1].

In the present work, NiTi and SS wires 300 µm in diameter were laser welded in a butt-weld configuration. The welds were made using a Nd:YAG 5W (pulsed laser) with orbital welding facility to rotate the wires while welding. After welding, the specimens were mechanically polished and directly observed using SEM (BSE, EDX and SE), lamellae extracted using FIB for TEM observations, while others were analyzed in 3-dimensions using the X-ray tomography facility of the Swiss Light Source at the Paul Scherrer Institute [2].

In Figure 1, four main areas can be identified in such a weld. The upper part is the NiTi wire while the bottom one is the SS wire. In between, the welded region with a mixed composition appears gray, with a thin layer of a brittle phase (in white) between the weld and the NiTi wire and a few microporosities in black. Some of them have formed on small debris coming from the oxide skin present on the NiTi wire and entrained in the weld. As these oxides are not wetted well by the liquid, they act as nucleation precursors of porosities, and also as stress concentrators for crack initiation and propagation. This is clearly visible in Figure 2: the crack goes through the white brittle phase and stops when it reaches the NiTi base material, which is more ductile. [3]

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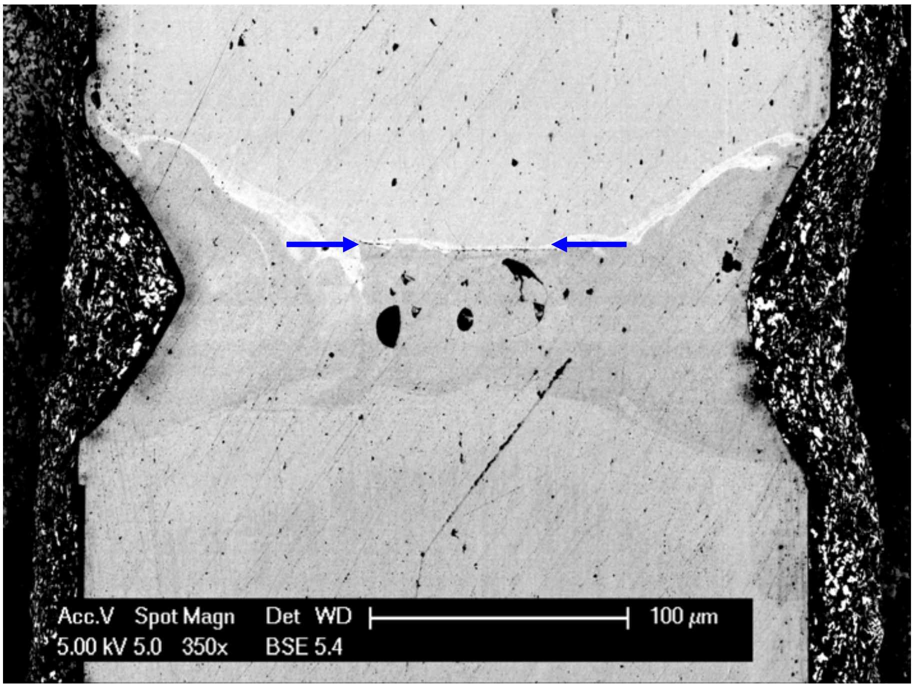

Figure 1. SEM/BSE image of a longitudinal section of a laser weld between NiTi (at the top) and SS (at the bottom) 300 μm diameter wires. The laser beam was mainly focused on the SS wire, which explains the low Ti composition of the weld pool and the localization of the brittle phase (white region) at the interface between the weld and the NiTi wire. The two blue arrows indicate the location of the remaining oxide skin that weakens the weld.

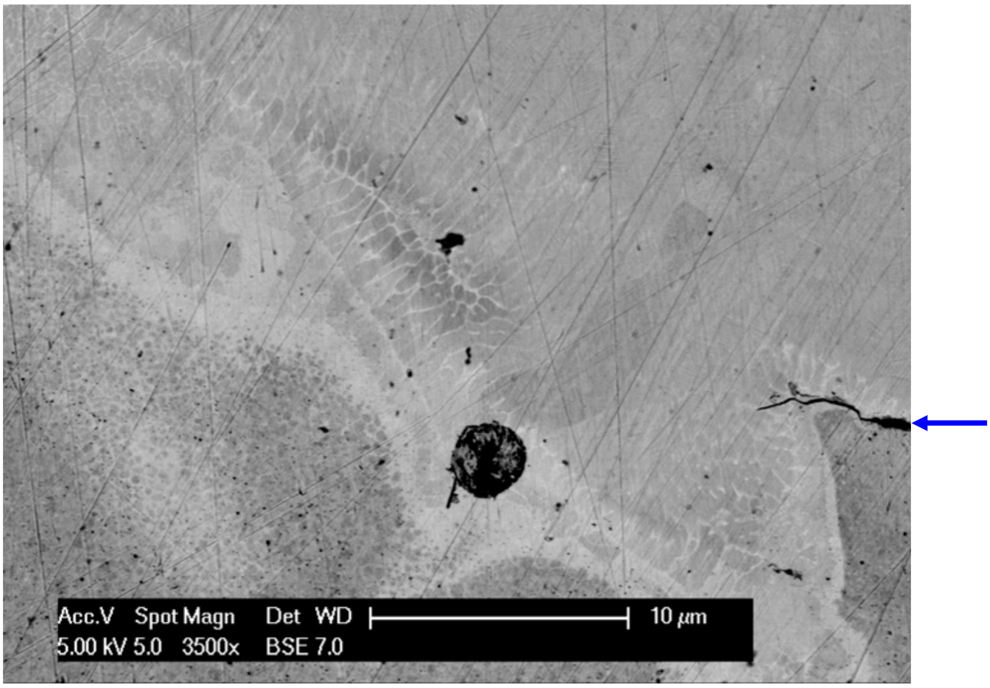

Figure 2. SEM/BSE image of the same sample as in Figure 1, but at higher magnification, near the crack initiation area. As can be seen, the crack stopped in the NiTi phase. The blue arrow indicates the oxide skin debris that act as diffusion barriers (significant jumps in compositions were observed by EDX).